

Investigation of the Health Status of Michigan Chemical Corporation Employees

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Clinical findings are reported for a group of 55 employees of the Michigan Chemical Corporation which manufactured FireMaster BP-6 from 1970 to 1974, in addition to a variety of other halogenated fire retardant chemicals. The results are compared with those from a group of male farm residents and consumers from Michigan examined at the same time.

An increased prevalence of chest and skin symptoms was observed, compared with farmers. Skin symptoms were more prevalent among former PBB production personnel. Musculoskeletal symptoms were less prevalent among these workers than among farmers. Serum PBB concentrations were significantly higher than among farmers. Blood chemistry results were similar for workers and farmers. However, both groups exhibited a significantly higher prevalence of elevated liver function tests (SGOT, SPGT) than a control population of nonexposed farmers. Both farmers and chemical workers showed an association of elevated CEA with serum PBB greater than 10 ppb.

In the past decade, concern over the loss of lives and property to fires has led to a vastly expanded market for chemical flame retardants. One or more of six elements—bromine, chlorine, phosphorus, nitrogen, boron, antimony—are commonly incorporated into various synthetics to reduce fabric flammability. Effective flame retardant additives for plastics, not as easily developed as those for fabrics, include brominated organic compounds, which are more effective than chlorinated ones (1). Polybrominated biphenyl compounds (PBB) have the desired property of reducing flammability without greatly affecting the flexibility of the base polymer. Since PBBs were also economically feasible, large-scale commercial markets rapidly developed for their use, especially in thermo plastic resins. In 1974, approximately 4.8 million pounds of hexabrominated biphenyl and 100,000 pounds of octabromobiphenyl and decabromobiphenyl were manufactured (2). In 1973, FireMaster BP-6 (principally hexabromobiphenyl) was accidentally added to animal feed in Michigan (3). Subsequent consumption of contaminated farm animal produce resulted

in widespread human exposure to PBB. Concern for the possible occurrence of adverse health effects evolved as a result of the accident, and clinical studies of persons exposed by ingestion of farm products were conducted (4, 5).

In addition to Michigan dairy farmers, a smaller population of individuals was exposed to the PBBs while employed at the manufacturing plant from the beginning of its production in 1970 until it ceased at the end of 1974. These Michigan Chemical Corporation (MCC) employees potentially had exposures in excess of the environmentally exposed farmers and consumers, with an earlier initial onset. Further, the route and quality of occupational exposure was probably different for these workers since they could have been directly exposed to the chemical mixture FireMaster BP-6. In contrast, PBB consumed by farmers may have undergone metabolic differentiation in the animal food source. Careful clinical evaluation of these workers was therefore important. Michigan Chemical Corporation employees were included as a separate subgroup in the Environmental Sciences Laboratory's evaluation of possible adverse human health effects related to PBB during its survey of Michigan residents.

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Materials and Methods

Worker Population Studied

With the cooperation and assistance of the Oil, Chemical, and Atomic Workers International Union which represented production workers at the MCC, invitations to attend the clinical survey November 4–11, 1976 in Grand Rapids, Michigan, were offered to all employees of the company. Approximately 270 individuals were employed in the plant at that time. Production of FireMaster products in this facility had been discontinued at the end of 1974. Workers in the PBB department had been shifted to other departments or had found employment elsewhere. While all employees were invited, special emphasis was placed on participation by those who had worked directly in the PBB production area.

Comparison Group

It was felt to be useful to compare the chemical workers with PBB exposed farmers examined at the same time. The sex distribution of the chemical workers and farmers differed significantly. For this analysis, only randomly invited male farmers and male consumers of produce from those farms, were used for comparative purposes. No other criteria were used in limiting the comparison group.

Examination Protocols

Questionnaires, examinations, and procedures utilized in study of the Michigan Chemical Corporation workers were identical with those used for the other groups participating in the survey (6). However, in addition, workers were asked whether acute symptoms had ever been experienced while working in the plant.

Statistics

Only symptoms which were reported as being currently present or which had occurred in 1976 were included in this initial evaluation. Grouping of symptoms and laboratory test results were the same as those used in the analyses reported elsewhere (6–9). Symptoms experienced which were attributable to acute exposures in the plant were not separated from chronic symptoms.

A 2×2 chi-square test was used to statistically test the significance of differences in prevalences.

Results

Fifty-five current employees of the Michigan Chemical Corporation were examined (52 men and 3 women). Occupational histories recorded detailed

work experience and exposures prior to employment by the Michigan Chemical Corporation as well as all job categories held and known exposures on those jobs while at the MCC. As is common in many chemical plants, workers handled many different chemicals and did not know the names of all of them. We have been unable to obtain a list of all chemicals used and manufactured by the MCC in order to supplement the information supplied by the workers examined. Ten of those examined had formerly worked directly in the FireMaster BP-6 production area. The other 45 persons worked in other departments in the plant. Six individuals had begun employment in 1975 or later and thus had not been in the plant during the period of active manufacture of PBB.

Table 1 summarizes the prevalence of symptoms present at the time of examination or which had occurred during 1976. The prevalence of symptoms among the chemical workers as a group was significantly greater than among the farmers in the categories "chest" ($\chi^2 = 14.7, p < 0.001$) and "skin" ($\chi^2 = 4.8, p < 0.05$). Significantly fewer symptoms were reported in the "musculoskeletal" category ($\chi^2 = 4.6, p < 0.05$). The excess chest symptoms were clustered among the workers in non-PBB departments. The PBB department workers experienced symptoms in the skin category significantly more frequently than the non-PBB workers ($\chi^2 = 5.2, p < 0.05$).

For all MCC workers, Table 2 contains an analysis of the prevalence of symptoms by the length of time the workers had been employed by the Michigan Chemical Company. With the exception of gastrointestinal symptoms, all categories showed greater prevalence as duration of employment increased. This trend was also seen for prevalence of symptoms with increasing age (Table 3). Because age is associated with longer duration of employment, it is difficult to determine the relative contribution of each to the observed increase in prevalence.

An automated analysis of blood enzyme levels was obtained for each survey participant (7). Table 4 shows the prevalence of abnormal liver function tests among the workers and among the dairy farmers in the comparison group. With the exception of alkaline phosphatase ($\chi^2 = 9.3, p < 0.01$) the two groups were not significantly different. The prevalence of abnormalities among the PBB and non-PBB department workers was also not significantly different.

Table 5 summarizes the prevalence of abnormal liver function tests by duration of employment in the plant. With the exception of alkaline phosphatase, all tests showed increased prevalence of

Table 1. Prevalence of symptoms among 55 Michigan Chemical Corporation employees.

Job category	Total number examined	Chest		Skin		Neurological		Musculoskeletal		Gastrointestinal	
		No.	%	No.	%	No.	%	No.	%	No.	%
PBB department	10	1	10	7	70	4	40	3	30	1	10
Other departments	45	16	36	14	31	15	33	10	22	7	16
Total	55	17	31	21	38	19	35	13	24	8	15
Male, randomly invited farmers, and consumers	204	21	10	48	24	86	42	80	39	35	17

Table 2. Prevalence of symptoms among 55 Michigan Chemical Corporation workers by duration of employment.

Duration employment, yr	Total number examined	Chest		Skin		Neurological		Musculoskeletal		Gastrointestinal	
		No.	%	No.	%	No.	%	No.	%	No.	%
< 5	20	5	25	7	35	6	30	3	15	2	10
> 5	35	12	34	14	40	13	37	10	29	6	17
Total	55	17	31	21	30	19	35	13	24	8	15

Table 3. Prevalence of symptoms among 55 Michigan Chemical Corporation employees by age.

Age, yr	Total number examined	Chest		Skin		Neurological		Musculoskeletal		Gastrointestinal	
		No.	%	No.	%	No.	%	No.	%	No.	%
< 36	37	9	24	12	32	11	30	6	16	6	16
> 36	18	8	44	9	50	8	44	7	39	2	11
Total	55	17		21		19		13		8	

Table 4. Prevalence of abnormal liver function tests among 55 Michigan Chemical Corporation employees.

Group	Total number examined	Alkaline phosphatase > 95		SGOT > 40		SGPT > 45		LDH > 225	
		No.	%	No.	%	No.	%	No.	%
Michigan Chemical Corporation	55	14	25	5	9	6	11	4	7
Farmers and consumers	192	22	11	28	15	22	11	22	11

Table 5. Prevalence of abnormal liver function tests among 45 Michigan Chemical Corporation employees according to duration of employment.

Duration of employment, yr	Total number examined	Alkaline phosphatase > 95		SGOT > 40		SGPT > 45		LDH > 225	
		No.	%	No.	%	No.	%	No.	%
< 5	20	5	25	1	5	1	5	1	5
> 5	35	9	26	4	11	5	14	3	9

abnormalities among those with more than five years in the plant. While a definite trend is apparent, statistically the differences do not reach the $p < 0.05$ level of significance. In the Wisconsin and Michigan groups reported elsewhere (7), the prevalence of abnormal liver function tests was not associated with age.

Table 6 shows the CEA titers by duration of employment. Although the differences do not reach the $p < 0.05$ level of significance, those with the longer duration of employment tended to have the higher prevalence of abnormal titers. Compared to the Michigan farmers, the chemical workers as a group did not have a statistically significantly higher prevalence of elevated CEA titers. Considering only the workers with more than five years in the plant, a significantly higher prevalence of elevated titers was present when compared to the farmers ($\chi^2 = 5.4$, $p < 0.02$). There was no statistically significant difference between the PBB and non-PBB department workers.

Table 6. Prevalence of elevated CEA titers among 55 Michigan Chemical Corporation employees according to duration of employment.

Duration of employment, yr	Total number examined	CEA > 2.5ng/ml	
		No.	%
< 5 years	20	3	15
> 5 years	34	10	29
Total	54 ^a	13	24
Male Michigan farmers and consumers	191	26	13.6

^a CEA titer was not studied in one Michigan Chemical Corporation worker.

Table 7 summarizes the distribution of PBB serum concentrations of the chemical workers, all Michigan farm residents with available results and the male random and consumer groups. The distributions are markedly different. All 55 workers tested (including the six who began employment after the company had stopped production) had

PBB serum levels above 1 ppb, while 23% of all the farmers and 13% of the male random group had values below that level. Of the workers, 5% had values over 1,000 ppb while only 0.4% of the farmers, and 0.9% of the random males had values in that range. Nine of the ten with histories of work in the PBB department had values above 10 ppb.

Discussion

The Michigan Chemical Corporation manufactures many chlorinated and brominated chemicals. Several brominated organic compounds such as Tris (tris-2,3-dibromopropyl phosphate), bistetra-bromophenol, tetrabromophthalic anhydride, hexabromobenzene, and 2,4,6-tribromophenol have been made by this company, in addition to the hexabromobiphenyl product FireMaster BP-6. Because of this probable multiple agent exposure, we caution against attributing the findings solely to past PBB exposure. It is difficult to estimate the relative contribution of exposure to FireMaster BP-6 to the current symptoms and laboratory findings presented here. It is also possible that, since the 55 individuals examined were self-selected, they were not representative of all the employees of the Michigan Chemical Corporation.

These initial analyses of a clinical field study of 55 employees of a PBB producing plant have demonstrated that the prevalences of chest and skin symptoms among the chemical workers are different from those of a comparison group of male farmers also exposed to PBB. These differences can be explained by the different routes of exposure to PBB and other chemical agents experienced by these workers, compared with farmers.

The increased prevalence of chest symptoms among the chemical workers, especially the non-PBB department group, probably reflects exposure to respiratory irritants such as bromine and chlorine which are present in the plant. However, a role for PBB in inducing these symptoms cannot be excluded, especially as one of a complex of factors. PCB has been shown to be concentrated in the

Table 7. Serum PBB levels in 55 Michigan Chemical Corporation employees and 524 Michigan farm residents.

Group	Total number examined	PBB concentration									
		0.0–1.1 ppm		1.1–9.9 ppm		10.0–99.9 ppm		100.0–999.9 ppm		≥ 1000 ppm	
		No.	%	No.	%	No.	%	No.	%	No.	%
Michigan Chemical Corporation employees	55	0	0	28	51	17	31	7	13	3	5
Michigan farm residents	524	124	23	309	59	70	14	19	4	2	0.4
Male, random invitation farmers and consumers	109	13	12	70	64	19	17	6	6	1	1

bronchial epithelium of mice (10) and it would not be surprising if the same were true for PBB. Thus, the role of PBB in relation to chest symptoms and disease warrants further investigation.

Increased prevalence of skin symptoms, especially among the PBB production personnel, may be due to skin absorption as an important route of exposure for workers. The PBB department workers had a greater opportunity for dermal contact with FireMaster BP-6 than either the non-PBB department workers or farmers. Other chemicals present in the plant, either currently or in the past, could also contribute to the high prevalence of skin symptoms. Additional analyses are underway to separate irritant skin reactions from acneogenic ones which would be attributable to brominated aromatic hydrocarbon exposure (11). Kimbrough et al. (12) and Hass and colleagues (13) have reported PBB to produce hyperkeratosis in the rabbit ear, typical of acneogenic agents.

The decreased prevalence of musculoskeletal symptoms among the chemical workers may be related to the fact that as a group they were considerably younger than the farmers. Only one-third of the chemical workers were over age 35, compared to 53% of the farmer group. When compared within age groups, the statistical significance of the musculoskeletal symptoms fell below the $p < 0.05$ level of significance. It may also be that outdoor work with greater extremes of temperature was a factor in the prevalence of the farmers in musculoskeletal symptoms.

Two years after manufacture of FireMaster BP-6 ceased, the levels of PBB in the serum of the workers, especially those who had worked in the PBB department, were significantly higher than the comparison group. Other laboratory tests performed (liver function tests, CEA titers) did not differ significantly for the chemical workers and the PBB exposed farmers. It should be noted, however, that the prevalence of elevated liver function tests in the Michigan group was significantly different from a control population of totally non-PBB exposed farmers. Thus, MCC workers and PBB exposed

farmers exhibit similar patterns of abnormality.

An association between CEA titer and serum PBB concentrations greater than 10 ppb were shown by Anderson et al. (8) among farmers. It is of interest to note that among the MCC workers the same association is present. Of 27 workers with serum PBB greater than 10 ppb, 8 (30%) had elevated CEA titers, compared to 5 of 28 (18%) with serum PBB levels less than 10 ppb. The mechanism for and significance of, these findings are not now known.

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